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13. ABSTRACT (Maximum 200 words)

Over the past three years, under the support of Army Basic Research Grant, the proposer has studied nonlinear hyperbolic-parabolic partial differential equations related to gas dynamics and mechnics. Hyperbolic conservation laws with relaxation are studied with applications to kinetic theory, elasticity with memory and gas flow with thermo-non-equilibrium in mind. Nonlinear waves for the compressible Navier-Stokes equations are studied for their stability and time-asymptotic behavior. The singular behavior of the magenetohydrodynamics shock waves in the small dissipation limits is clarified, in particular, it is shown that intermediate shocks are stable uniformly with regards to the strength of dissipations only for 2-dimensional model, and not for 3-dimensonal model.

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Research Activities

My research centered on the study of stability and instability of nonlinear waves for nonlinear partial differential equations arising in kinetic theory, compressible flows and elasticity. Th following papers have been written with the support of the ARO grant:

1. (with D. Hoff) The inviscid limit for the Navier-Stokes equations of compressible, instropic flow with shock data, Indiana Univ. J. 38 (1989) 861–915.
2. Nonlinear waves for viscoelasticity with fading memory, J. Diff. Equ. 76 (1988) 26–46.
3. Nonlinear resonance for quasilinear hyperbolic equation, J. Math. Phys. 28 (1987) 2593–2602.
4. (with Z. Xin) Nonlinear stability of rarefaction waves for compressible Navier–Stokes equations, Comm. Math. Phys. 118 (1988) 451–465.
5. (with S. Hsu) Nonlinear singular Sturm–Liouville problem and application to transonic flow through a nozzle, Comm. Pure Appl. Math. 43 (1990), 31-62.
6. (with T. Zheng) A scalar combustion model, Arch. Rational Mech. Anal. to appear.
7. (Z. Xin) Stabilitv of viscous shock waves associated with a nonstrictly hyperbolic conservation law, (preprint).
8. (S. Cox) Zero memory limit for a viscoelasticity model with Riemann data, (preprint).
9. On the viscosity criterion for hyperbolic conservation laws, (preprint).
10. (Z. Xin) Over compressive shock Waves onlinear volution equations that change types, ed. B. Keyfitz and M. Shearer, IMA volumes in Math. Appls. Vol. 27 (1990) 149–145.

[1] and [4] consider the the compressible Navier–Stokes equations. These are the most important equations for gas dynamics. In [1] we study the zero dissipation limit of viscous flow with a shock wave. Interesting behaviors such as discontinuity and shock layers are analyzed. [4] and earlier works of the author on Euler equations show that Navier–Stokes and Euler equations are time-asymptotically equivalent for expansion waves. [2] and [8] study elasticity with memory. [2] constructs nonlinear waves and studies their qualitative properties. [8] studies the stability of travelling waves which are developed through discontinuity data. The result implies that the zero- memory limit exists after the initial layer and is an elastic shock. Currently Chen of U. Chicago and the author are finishing a paper on more general questions of the zero relaxation limit. [3] studies hyperbolic conservation laws with a moving source. We found nonlinear stability and instability, and changing types of waves due to nonlinear resonance of the source, the convection and compression of the flux. Such phenomenon exists for gas flow through a duct of varying cross section and MHD with a moving magnetic force. [5] considers viscous compressible flow through a nozzle. We study the existence and stability of stationary flow. Because of nonlinear resonance and the smallness of viscosity, the Surm-Liouville problem it gives rise to is singular and has nonlinear turning point. The analytical aspect is therefore distinct from previous works in the subject. In [6] a scalar combustion model is proposed. In spite of its simplicity it is capable of capturing some interesting instability properties of combustion waves. [7] and [10] study the stability of overcompressive shock waves for viscous and inviscid models. Such waves occur in multiphase flow. We show that they are

stable in a different sense from that of the classical shock waves in gas flows. Finally in [9] we consider the stability of intermediate shock waves for magnetohydrodynamics and nonlinear elasticity. These waves are easily shown to be unstable from the inviscid theory. But we show that they are stable for the viscous model provided that they perturbation is not too large compared to the dissipative coefficients. Previous studies are mainly numerical and not definite. We argue from the time-invaiants and the principle of nonlinear superposition, ideas the author introduced earlier to study the compressible Navier-Stokes equations.

The ARO Grant, besides allowing the author to devote more time to do research, is also important for sparing the time necessary to direct Ph.D. students. S. Cox obtained his Ph.D. in Maryland, 1988, with a dissertation on elasticity with memory. P. Zingano and K. Zumbrun finished their Ph.D.'s at N.Y.U., 1990. Zingano studies expansion waves and Zumbrun generalized N-waves for non-genuinely nonlinear models. Currently Cox is working in industry, Zingano is doing MHD research with me, and Zumbrun is in Stony Brook working on crossing waves in multiphase flow.

Works for which substantial progresses have been made but not yet finished include the following: with Chen and Levermore we are finishing a study on relaxation model. We are able to justify the zero mean free path fluid approximation in the kinetic theory for a simple model the author proposed. The author is writing up a paper on the MHD shocks with analytical details for results announced in [9] above. With Xin we have found that compressible Navier-Stokes equation has more singular behavior near vacuum than that of the compressible Euler equations.

Curriculum Vitae

Tai-Ping Liu
[redacted]

EDUCATION

Institution	Degree	Date Awarded
National Taiwan University	B.S.	1968
Oregon State University	M.S.	1970
The University of Michigan	Ph.D.	1973

EXPERIENCE IN HIGHER EDUCATION

Institution	Rank	Dates
University of Maryland	Assistant Professor	1973-78
New York University	Visiting Member	1976-77
University of Maryland	Associate Professor	1978-79
University Michigan	Visiting Professor	1978-79
Univ. of Cal., Berkeley	Visiting Professor	Spring 1980
Math Research Center		
University of Wisconsin	Visiting Professor	Fall 1980
University of Maryland	Professor	1981-88
Academia Sinica, R.O.C.	Visiting Professor	1982-83
Kyoto University	Visiting Professor	Spring 1983
Mittag-Leffler Institute	Visiting Professor	Spring 1986
Ecole Normale Superior	Visiting Professor	Summer 1988
Courant Institute	Professor	1988-1990
Stanford University	Professor	1990-Present

PUBLICATIONS

RESEARCH ARTICLES IN JOURNALS

1. The Riemann problem for general 2×2 conservation Laws, Transactions of A.M.S., 199 (1974), 89-112.

2. The Riemann Problem for general systems of conservation laws, J. Diff.Equations 18 (1975), 218-234.

3. Existence and uniqueness theorems for Riemann problems, Transactions of A.M.S. 212 (1975) 375-382.

4. Uniqueness theorem of the Cauchy problem for general 2×2 conservation laws, J. Diff. Eqs. 20 (1976)369-388.

5. Shock waves in nonisentropic gas flow, J. Diff. Equations 22 (1976) 442-452.

6. The entropy condition and the admissibility of shocks, J. of Math. Anal. and Applications 53 (1976) 78-88.

7. Solutions in the large for equations of nonisentropic gas dynamics, Indiana Univ. J. 26 (1977) 144-177.

8. Initial-boundary value problems for gas dynamics, Arc. Rat. Mech. and Anal. 64 (1977) 137-168.

9. Asymptotic behavior of solutions of general systems of nonlinear hyperbolic conservation laws, Indiana Univ. J. 27 (1978) 211-253.

10. Decay to N-waves of solutions of general systems of nonlinear hyperbolic conservation laws, Comm. Pure Appl. Math. 39 (1977), 585–610.

11. Large-time behavior of solutions of initial and initial-boundary value problem of general system of hyperbolic conservation laws, Comm. Math. Phys. 55 (1977) 163-177.

12. Linear and nonlinear large-time behaviors of solutions of hyperbolic conservation laws, Comm. Pure Appl. Math. 30 (1977) 767-796.

13. The deterministic version of the Glimm scheme, Comm. Math. Phys. 57 (1977) 135-148.

14. Invariants and asymptotic behavior of solution of a conservation law, Proceedings of A.M.S. 71 (1978) 227-231.

15. Free piston problem for gas dynamics, J. of Diff. Equations 39 (1978), 175-191.

16. (with S. Antman) Traveling waves in hyperelastic rods, Quarterly of Appl. Math. 36 (1979), 377-400.

17. Development of singularities in the nonlinear waves for quasilinear hyperbolic partial differential equations, J. Diff. Equations 33 (1979) 92-111.

18. Quasilinear hyperbolic systems, Comm. Math. Phys. 68 (1979) 141-172.

19. Transonic gas flow in a duct of varying area, Arch. Rat. Mech. and Anal. 80 (1982) 1-18.

20. (with J. Smoller) On the vacuum state for isentropic gas dynamics equations, Advances in Math. 1 (1980) 345-359.

21. Admissible solutions of hyperbolic conservation laws, Memoirs, Amer. Math. Soc. No. 240, 1981.

22. (with C.H. Wang) On a system of nonstrictly hyperbolic system, J.D.E. 57 (1985) 1-14.

23. Nonlinear stability and instability of transonic flows through a nozzle, Comm. Math. Phys. 83 (1982) 243-260.

24. (with a Chorin and Z. H. Teng) Riemann problems for reacting gas with applications to transitions, SIAM J. Appl. Math. 42 (1982), 964-981.

25. (with M. Pierre) Source-solutions and asymptotic behavior in conservation law, J. Diff. Equ. 51 (1984) 419-441.

26. Resonance for quasilinear hyperbolic equation, Bulletin Amer. Math. Soc. 6 (1982) 463-465.

27. (with C. Li) Asymptotic states for hyperbolic conservation laws with a moving source, Advances in Appl. Math. 4 (1983) 353-379.

28. (with H. Galz) The asymptotic analysis of wave interactions and numerical calculations of transonic nozzle flow, Advances Appl. Math. 5 (1984) 111-146.

29. (with L. P. Huang) Piecewise steady elements and Godunov-type difference scheme for duct flow, Comp. & Maths. with Appls. 12A (1986) 366- 388.

30. Pointwise convergence to N-waves for hyperbolic conservation laws, Bulletin, Inst. Math., Academia Sinica 15 (1987) 1-17.

31. Hyperbolic conservation laws with relaxation, Comm. Math. Phys. 108 (1987) 153-175.

32. Nonlinear stability of shock waves for viscous conservation laws, Memoirs, Amer. Math. Soc., No. 328, 1985.

33. Shock waves for compressible Navier-Stokes equations are stable, Comm. Pure Appl. Math. 39 (1986) 565-594.

34. (R. Caflisch) Stability of shock waves for the Broadwell equations, Comm. Math. Phys. 39 (1986), 565-594.

35. (with I-L. Chern) Convergence to diffusion waves of solutions for viscous conservation laws, Comm. Math. Phys. 110 (1987) 503-517.

36. (with D. Hoff) The inviscid limit for the Navier-Stokes equations of compressible, instropic flow with shock data, Indiana Univ. J. 38 (1989) 861–915.

37. (with Z. Xin) Over compressive shock waves nonlinear evolution equations that change types, ed. B. Keyfitz and M. Shearer, IMA volumes in Math Appls. Vol.27 (1990) 189-145.

38. Nonlinear waves for viscoelasticity with fading memory, J. Diff. Equ. 76 (1988) 26-46.

39. Nonlinear resonance for quasilinear hyperbolic equation, J. Math. Phys. 28 (1987). 2593-2602.

40. (with Z. Xin) Nonlinear statbility of rarefaction waves for compressible Navier–Stokes equations, Comm. Math. Phys. 118 (1988) 451–465.

41. (with S. Hsu) Nonlinear singular Sturm-Liouville problem and application to transonic flow through a nozzle, Comm. Pure Appl. Math. 43 (1990), 31–62.

42. (with T. Zheng) A scalar combustion model, Arch. Rational Mech. Anal.to appear.

43. (with Z. Xin) Stability of viscous shock waves associated with a nonstrictly hyperbolic conservantion law, (preprint).

44. (with S. Cox) Zero-memory limit for a viscoelasticity model with Riemann data (preprint).

MEMBERSHIP IN HONORARY OR PROFESSIONAL SOCIETIES

American Mathematical Society, SIAM

SERVICE TO THE MATHEMATICAL COMMUNITY

Reviewer, Zentralblatt fur Mathematik
Reviewer, Mathematical Reviews
Committee on Translation in Chinese, A.M.S.
Organizer, Special session in Applied Mathematics,
    Compressible flows, April 1984 in A.M.S. meeting.
U.S. Coordinator, AIT-CCNAA Joint Seminar on Differential
    Equations, Taiwan, June 1985.
U.S. Coordinator, U.S.-France, Joint Seminar on Hyperbolic
    Conservation Laws, France, Jan. 1986
Coorganizer, 1989 Conference on Nonlinear Waves, Academia Sinica, R.O.C.
Editor, J. Dynamics and Differential Equations

GRANTS AND CONTRACTS

NSF Grant 1976–Present
Independent Research Fund, N.S.W.C
NSF Grants for AIT-CCNAA and U.S.-Frnace Joint Seminars
and from U.S.-China Program
Army Basic Research Grant 1986–present
AFOSR Grant 1988–present

AWARDS AND PRIZES

Sloan Fellowship 1979-81
Guggenheim Fellowship 1982–83

INVITED TALKS TO CONFERENCES AND WORKSHOPS 1989–90

Conference on Fluid Mechanics, Trieste, January 1989
Workshop on Mixed Types and Phase Transition, IMA, Minn., March 1989
Workshop in Multidimensional Hyperbolic Waves, IMA, Minn., April 1989
Conference on Nonlinear Analysis, Taipei, June 1989
Conference on Nonlinear P.D.E., Kyoto, August 1989
Workshop on Stability of Nonlinear Waves, Naples, October 1989
Workshop on Hyperbolic P.D.E., Bonn, March 1990
International Conference on Nonlinear Hyperbolic Problems, Uppsala, June 1990
Elba Conference on Variational Problems and Nonlinear P.D.E.,
Italy, October 1990
Workshop on Nonlinear P.D.E., M.S.R.I. Berkeley, October 1990
Workshop on Phase Transition, IMA, Minn. October 1990.
Japan–Taiwan Conference on Reaction–Diffusion Equations, Taipei,
December 1990.